<u>Intensity-correlation imaging of dark objects in space</u>

Dmitry V. Strekalov, Baris I. Erkmen, and Nan Yu

Jet Propulsion Laboratory, California Institute of Technology

Direct intensity measurement, by an eye or by a detector, has always been the foundation of observation astronomy. This technique is often successfully complemented by other types of measurements, for example those relying on intensity correlations. The intensity-correlation imaging in astronomy stems from the early pioneering research by Hanbury Brown and R.Q. Twiss carried out in 1960's. The excitement caused by their discovery soon had faded because of insufficient performance of available optical detectors as well as a scope of its applications, mainly limited to measuring star radii. At the present, however, the area becomes increasingly active thanks to a breakthrough in the optical detectors technology. It can be expected to completely revive and flourish during the time span of the projected Roadmap. We would like to point out an interesting novel aspect of this technique which could significantly enhance its versatility and, we believe, belongs on the Roadmap. This is the intensity-correlation imaging, aka "ghost" imaging, of *dark* extraterrestrial objects.

To our knowledge, all former research on astronomical applications of intensity correlation was aimed at imaging of *bright objects*. We have realized how this technique can be applied to imaging of *dark objects*, partially shadowing celestial light sources. This understanding has been inspired by the success of Kepler mission and by the original exploration of quantum ghost imaging by the PI in 1995. Fig.1 outlines one possible implementation of our approach, with one ground and one space observers. The underlying physical principle that enables intensity-correlation imaging is the property of thermal photons of the same optical mode to "group" together, and the ability of a scattering object to modify the spatial form of this correlation function. The measurement is based on two photo detectors' signals that are analyzed for the photon detection pulses (or photo currents) correlation. Since the correlation measurement does not preclude a conventional intensity measurement, which may be carried out simultaneously by the same set of detectors, we consider our technology as an upgrade to conventional observational astronomy ground based or space missions rather than their alternative.

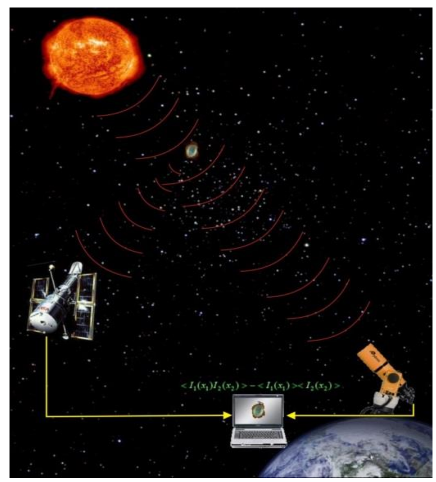

Fig. 1. A cartoon representation of one possible version of a dark space object correlation imaging.

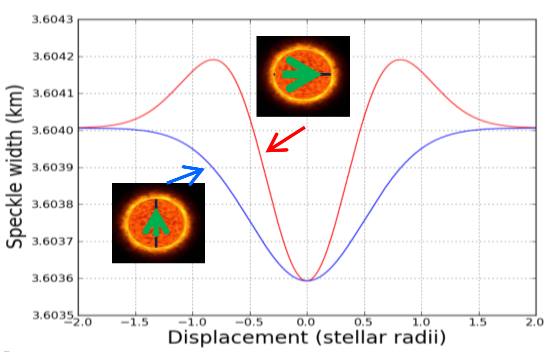

Fig. 2. Theoretical analysis shows that the correlation-imaging signature from a planet passing in front of a star depends on its orbit's orientation.

The list of space objects that can be studied with our approach includes exoplanets orbiting around bright parent stars, Kuiper belt asteroids "serendipitously" obscuring bright stars and galaxies, gravitational lenses due to black holes, dark matter and potentially others. The motivation for developing this approach lies in its certain aspects beneficial in astrophysics observations, such as strong background light suppression and the flexibility in distributing the imaging optics among the two channels. More importantly, this approach gives access to parameters that may not be available from conventional astronomy observations. For example, we predict that the correlation measurement is sensitive to the direction of a planet transient in front of a star in a Kepler-style observation, as illustrated in Fig. 2.

Our research has been supported by the NIAC program since 2011 as the Phase-I effort, and now has been selected for the Phase-II, as an acknowledgement of its merit and future benefit for astrophysics. The timelines of the NIAC program are similar to those of the presently developed Roadmap. In particular, our NIAC effort is expected to reach the mission-ready state around 2024.